Optimal Timeout of the Optically Distributed 802.11 Network

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Abstract: This paper investigates the MAC-protocol performance of an IEEE 802.11 Network that deploys Radio over Fibre technology to distribute radio frequency signals from a central location to remote antenna sites for nomadic users. Our study is based on the current DCF access scheme specifications using both the Basic access method and the RTS/CTS access mechanism. The theoretical results show that there is a specific optimum timeout value concerning each limited length of fibre where the throughput can be maximised.

1. Introduction

The principal inspiration of this paper is to form a Radio over Fibre (RoF) system in which the Remote Antenna Unit (RAU) is very compact and the radio channel assignment is performed in a centralised location away from the remote unit. In such a system, the majority of the base station components are positioned at a central location where the signal processing is carried out. Figure 1 illustrates this design, where the main unit, i.e. the Base Station (BS), and its antenna, i.e. RAU, are separated and linked together by the means of optical fibre. This results in a less complex and more compact RAU.

A major issue that arises is the applicability of deploying a fixed length of optical fibre into a standard IEEE 802.11 architecture. We evaluate the MAC performance of the proposed RoF system, in terms of the throughput, by varying the minimum standard timeout value defined in the IEEE 802.11 standard. In addition, we explore an approach by which the optimum timeout value can be obtained within a standard 802.11 system. This investigation then continues with the aim of pinpointing this optimum value for longer optical fibres in the system.

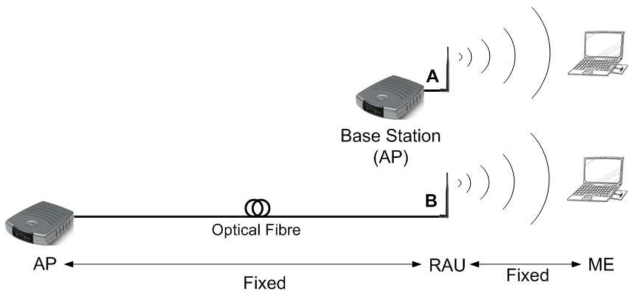

Figure 1: The basic overview of the planned RoF architecture

2. Overview of the IEEE 802.11 MAC Protocol

The 802.11 Medium Access Control Layer (MAC) is involved with the management of communications between various stations. It also has a common functionality for all types of physical layer, i.e. Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS), Infrared (IR) and Orthogonal Frequency Division Multiplexing (OFDM). In particular, the IEEE 802.11b DSSS supports data rates of 1, 2, 5.5 and 11 Mbps depending on radio conditions in the 2.4 GHz ISM band. The MAC 802.11b standard supports two schemes based the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) to access the shared wireless medium. They are called the Basic Access mechanism and the RTS-CTS Access method.

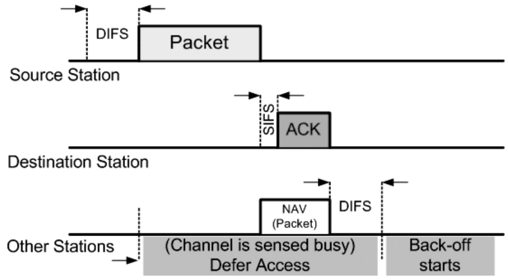

Figure 2: The Basic Access Method

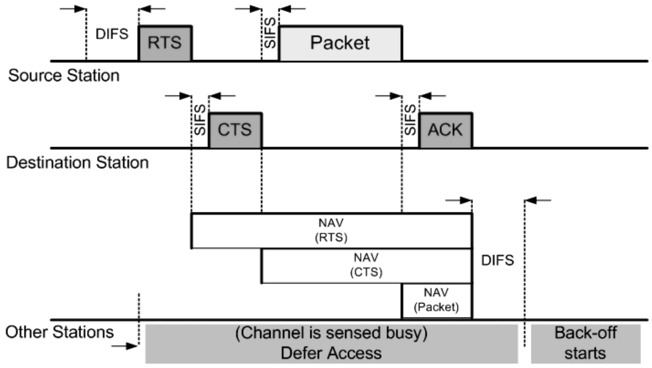

Figure 3: The RTS-CTS Access Mechanism

In the case of deploying the 'Basic Access Method', shown in Figure 2, after a successful transmission, the destination station waits for a Short Inter-frame Space (SIFS) interval and then sends an Acknowledgement packet (ACK) to confirm the correct reception of data. The same procedure is applied when the 'ack' (TCP data packet) is sent back to the source station, to provide confirmation of the successful reception of data at the TCP layer.

The second method, illustrated in Figure 3, uses a completely different approach. In this case, the involved stations, i.e. stations activating the Request To Send (RTS) and the Clear To Send (CTS) packets, have the power to control the use of the medium between them. This scheme attempts to reserve the shared medium for the time duration needed to transfer the actual data frame prior to its transmission. During this period, all stations in the reserved area are restricted from transmission even though the channel is idle. The IEEE 802.11 standard adopts the RTS-CTS method when the size of the data frame is larger than a predefined threshold [1] [2].

According to Figure 2 and Figure 3, when the optical fibre is inserted into the system each packet will go through the fibre delay. The increased delay due to the inserted fibre is more severe in the RTS-CTS method than the Basic Access mechanism since there are more packets involved.

The following equation calculates the propagation delay for each packet passing through the fibre link.

$$\frac{c}{n} = \frac{3\times 10^{8}}{1.54} = 194.81 \, {}^{m}\!/_{\mu s} \tag{1}$$

Where c is the speed of light and n is the reflective index of the fibre. According to equation (1), each 10µs delay is equivalent to 1948.1m of optical fibre (for each transmission direction).

3. Performance Evaluation

A mathematical model was created to examine the optimum timeout value that could be used within a standard 802.11b system for 1948m of fibre. All the parameters used in the model are given in Table 1. As defined in the IEEE 802.11b standard, the minimum timeout value is calculated in Equation (2) concerning both the Basic and RTS-CTS mechanisms [3].

$$Timeout = (SIFS + CTS \ (or \ ACK) + Slot\_Time) \tag{2}$$

The deployment of 1948m of optical fibre adds an extra 10µs delay (i.e. exactly one *Slot_Time* for both transmission directions) to the MAC layer. Figure 4 illustrates our assumption where the response time of the receiving station is modelled on a Gamma function with a spread of 20µs.

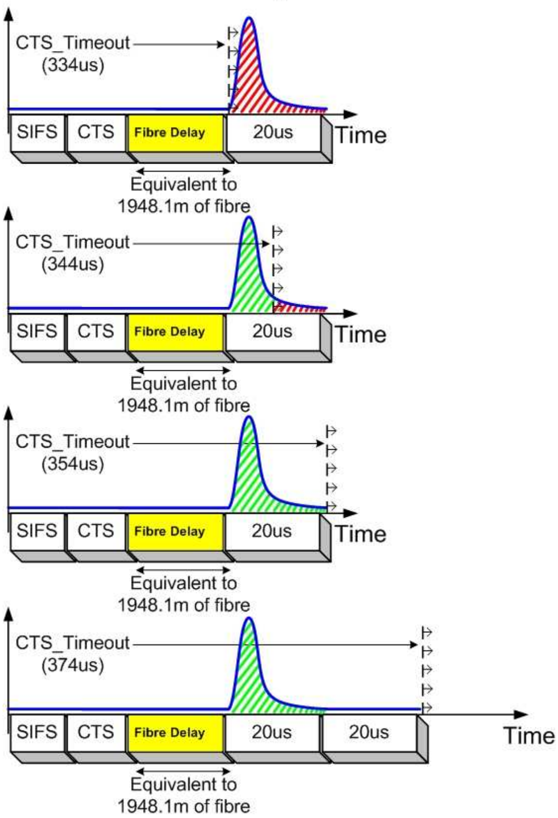

Figure 4: Probability of Successfully Transmitting Packets against Timeout

Table 1: Numerical Parameters used

Slot_Time	20 µs
SIFS	10 µs
DIFS	50 µs
PLCP Preamble	144 bits
PLCP Header	48 bits
MAC Header	240 bits
CRC	32 bits
Channel bit rate	1 Mbps
RTS	160 bits
CTS	112 bits
ACK	112 bits
Air propagation delay (δ)	< 1µs
Fibre Reflective Index (n)	1.54
L_{MPDU_1}	8000 bits
L_{MPDU_2}	300 bits
L_{MSDU_1}	7728 bits

According to Figure 4, the system has to wait a minimum period of *SIFS+CTS (or ACK)+τ* (where τ is the fibre propagation delay) before it can proceed with the rest of the MAC signalling. Therefore, to successfully transmit a packet through 1948m of fibre, the timeout has to be increased. Increasing the timeout allows the system to wait longer in order to receive the acknowledgement packet (i.e. CTS or ACK) and will also have an effect on the total throughput of the connection. Note, in Figure 4, as the timeout value is increased the probability of successful packets rises from zero until it reaches its maximum.

The result of increasing the timeout value in both the Basic and RTS-CTS access mechanisms (for 1948m, 3896m and 7792m of fibre respectively) are shown in Figure 5 and Figure 6. Note that the throughput of the RTS-CTS method is slightly lower than the Basic access mechanism. This is due to the involvement of more overhead packets.

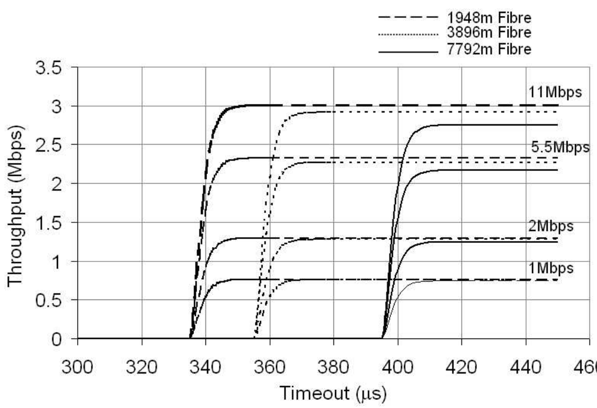

Figure 5: Throughput versus Timeout in the Basic Access Method

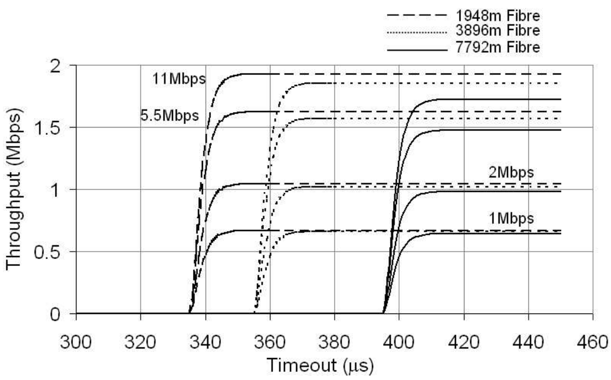

Figure 6: Throughput versus Timeout in the RTS-CTS Method

According to Figure 5 and Figure 6, when deploying 1948m of fibre, the throughput of an 11 Mbps system reaches 3Mbps at 352µs (in the Basic access method). For the same system that uses the RTS-CTS access mechanism, the throughput reaches 1.9Mbps at the same time. Therefore, to achieve 3Mbps of throughput, its optimum value in the first example, the timeout value should be set to at least 352µs. This value needs to be increased to 414µs to achieve 1.72Mbps of throughput for an 11 Mbps RTS-CTS system that deploys 7792m of fibre.

4. Conclusions

A general model for 802.11 networks was provided that can be applied to many scenarios in which a limited length of optical fibre is present. According to the deployment of 1948m of fibre, the optimum timeout value was seen to be in the region of 352µs where the throughput reached its maximum. This value had to be changed to 374µs and 414µs due to the use of 3896m and 7792m of fibre in the architecture of the IEEE 802.11b system respectively. It was also realised that the maximum throughput in the RTS-CTS mode was lower than the Basic Access method due to the involvement of more overhead packets.

References

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[3] J. Pavon, S. Choi, "Link Adaptation Strategy for IEEE 802.11 WLAN via Received Signal Strength Measurement", IEEE International Conference on Communications, Volume: 2, p.1108- 1113, 2003.